Review of White-Light-Flare studies since 1960s

Motivation: Vis and NIR observation on 2003-Oct-29

Can not download all references (>100) (some Journals are not accessible)

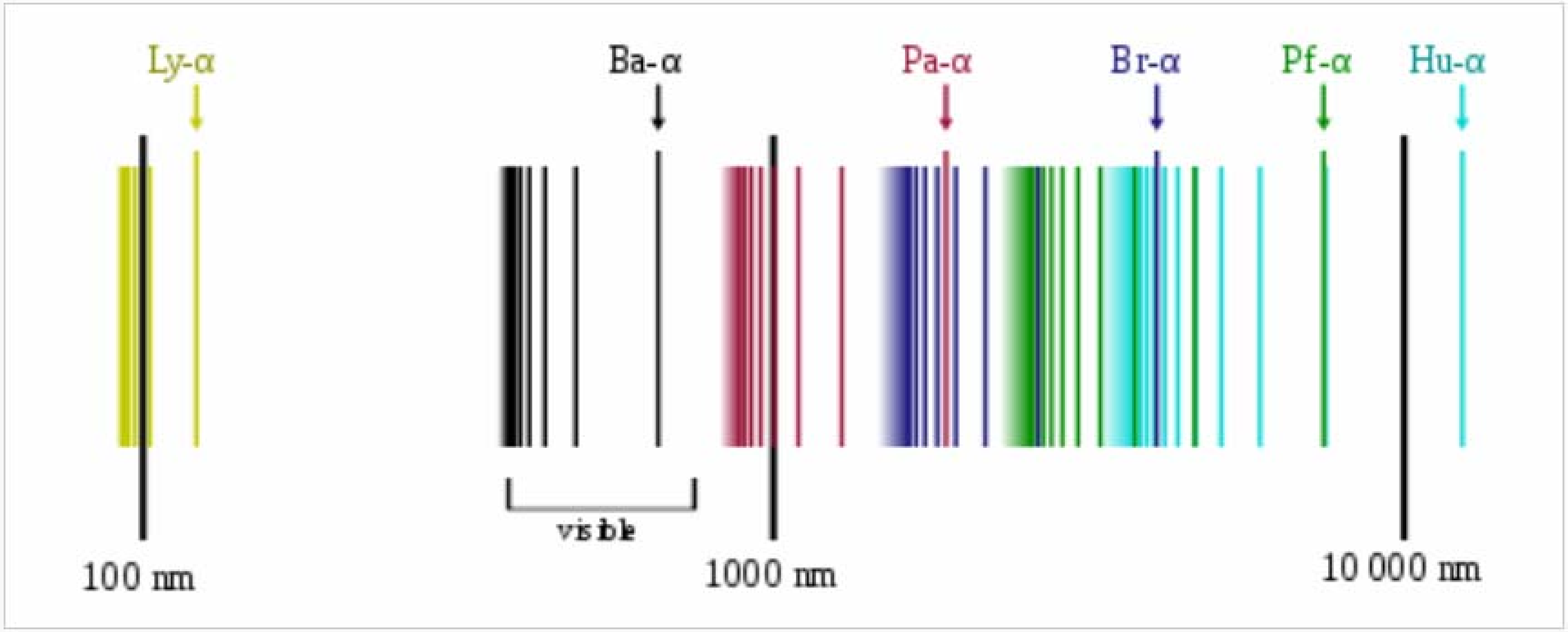
Some studies were not published (research notes…)

Some case studies are put into the table (slid #35)

No Radio analysis is included

Some phenomenon **(like blue-WL)** are not included because they only showed up few times in the literature and no longer being mentioned

{}, YX comments



The spectral series of hydrogen, on a logarithmic scale.

http://en.wikipedia.org/wiki/Hydrogen_spectral_series

Visible continua: 4000 ~ 7000 Å

↓

Optical continua…

1. First WFL observed on 1 September 1859 by Richard C. Carrington

2. Electrons enter denser regions, no complete theory of this process exists. People use approximation developed by Maeda 1963 for similar auroral problem.

3. Svestka 1970, Najita and Orrall 1970 show that energetic particles Can penetrate to upper photosphere Machado 1971 confirms that

4. Thin-Thick target:
   Thin: Arnoldy et al. 1968
   Brown, 1971
   Thick: Koch and Motz, 1959
   Hudson 1972

5. Hudson 1972: Continua dominate line emission due to high degree of nonthermal ionization

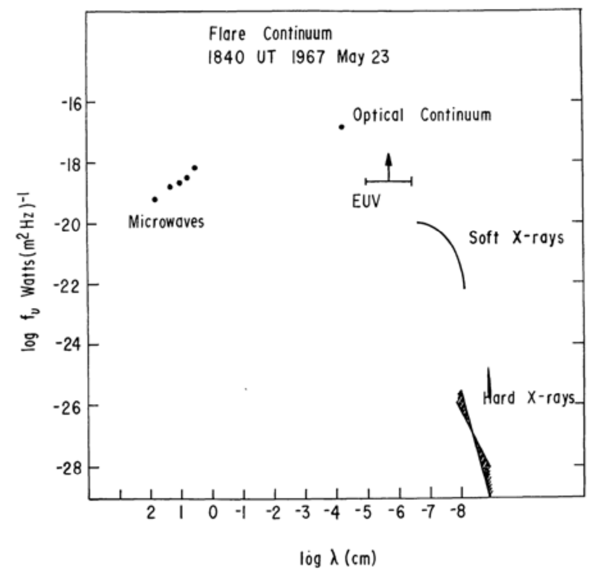


Fig. 1. Spectrum of solar emission at 1840 UT, 1967 May 23. The two X-ray spectra come respectively from Kane and Winckler (1968) and from Gardner (1971) with the spectral assumptions $\delta = 3$ and $\delta = 5$. Note that the time variation of the soft X-ray continuum clearly differs from that of the hard X-ray, EUV, optical or microwave continua. The EUV datum corresponds to an energy flux > 8 erg $(cm^2\ s)^{-1}$ concentrated at 300 Å. An effective wavelength nearer 1000 Å would move the lower limit upward.

Hudson 1972

6. Ohki & Hudson 1975 predicts IR continuum radiation in **Strong** Flares

7. Cortellesa & Paizis 1975 believes the emission from 400km but (8) think from > 1000km

8. Svestka 1976:
   a) most optical emission is spectral lines, which formed high in Chromosphere.
   b) Balmer series of hydrogen and singly ionized CA H and K lines are strongly enhanced. Balmer lines (**Wavelength (nm)** 656.3; 486.1 434.1; 410.2; 397.0; 388.9; 383.5; 364.6)

9. Machado 1976:
   a) λ-dependence of emission contradicts photospheric origin
   b) the continuum is NOT produced where the line cores are formed

Svestka 1976

10. Hiei 1982

- a) WL continuum can only be detected in most energetic flares
- b) ~ 30 events have been reported since 1859
  among them, only two have spectroscopic observations,
  see Gallegos et al. 1980 and Machado & Rust 1974.
- c) **Proton could not produce WL in this event**
- d) 3646 ~ 4000 Å H^- emission
  3600 ~ 3646 Å 50% free-bound 50% H^- emission
  Free-Free impossible
  bound-free is not good for their event, calculate ratio between two wavelengths
  H- emission is good and infers that the emission is from photosphere!

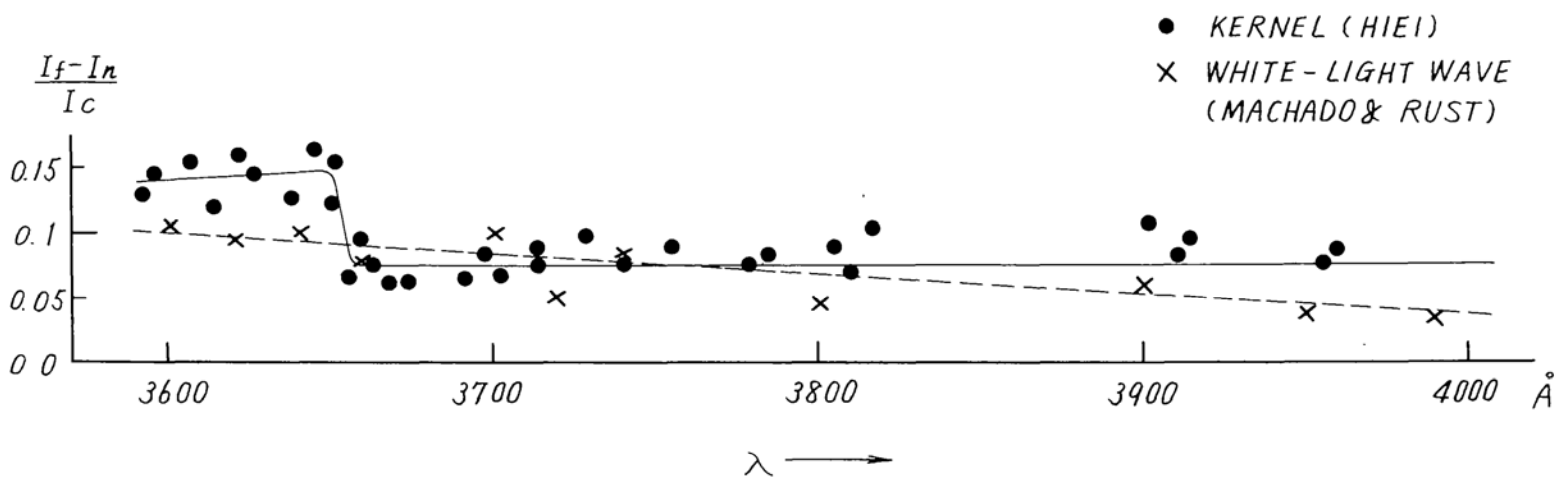


Fig. 7. Ratio of increased intensity of white-light continuum to normal continuum of the photosphere near the flare: dots are our results, crosses result by Machado and Rust (1974).

11. Hudson 1982

Protons could cause sufficient heating of the upper photosphere, but Emission from $\tau = 1$ is not significant.

12. Ryan et al. 1983

Late phase WL was not associated with either with Hard X-ray or γ-ray.

{remote brighting?}

13. Karlicky 1983

Electron beam was accelerated at 13:52:59UT in the chromosphere and anchored in the photosphere. {later on, there are papers talking about Lower reconnection}

14. Neidig 1983 a

a) At least **47** {1year from <30 to 47} flares have been observed in optical continuum up to now.

a) Optical emission 10^{28} erg/s for WLFs

b) WL could come from lower/upper photosphere or chromosphere, OR, **all layers to some degree.**

d) Local column density varies approximately two orders within 500 km (see Vernazza et al. 1981)

e) This event (1981-04-24) is due to **H- emission**

15. Dame & Cram 1983

The F2 (Machado et al. 1980) and LC (Lites & Cook 1979) models are not consistent with observations.

16. Neidig and Cliver 1983

a) 60 WLFs have been reported. {number increased again}
b) WLF frequency 15.5 ± 4.5 yr^{-1} during the maximum of solar cycle 21
   WLF frequency 5 – 6 yr^{-1} during the solar cycle 20 (McIntosh and Donnelly 1972)
   The reason is that shorter wavelengths (<4000) is used
c) WFL > X2

17. Neidig & Wiborg 1984

a) The event (1981-04-24) is due to **bound-free emission because of Paschen jump**
b) For the first time, people notice that spectrograph slit could be misplaced and hence could not include the brightest kernels

18. Boyer et al. 1985
A limb event observed in short wavelength

It looks not like footpoints

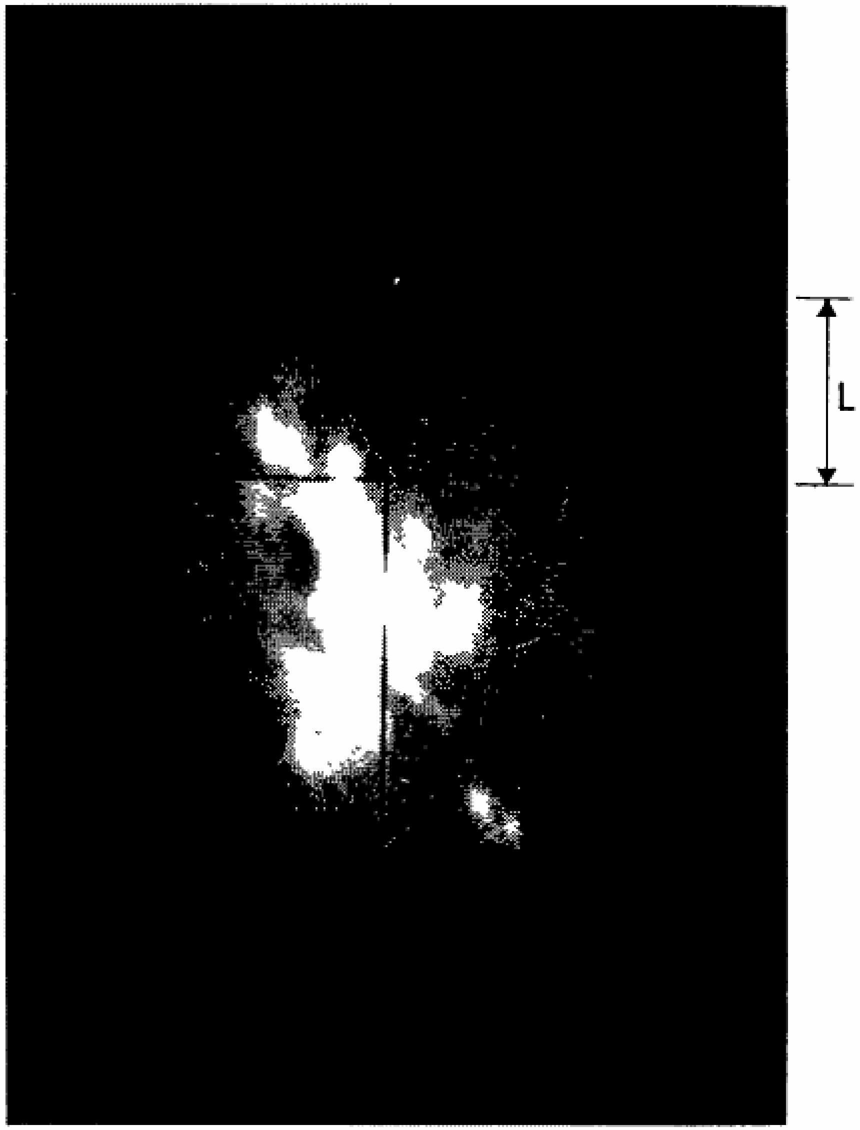


Fig. 1a

19. Aboudarham & Henoux 1986
Radiative losses in chromosphere are dominated by Balmer and Paschen Continua
$\mathcal{F}_{20}=10^{11}$ erg cm^{-2} s^{-1}

20. Aboudarham & Henoux 1989

a) Photosphere column density → 0.6 ~ 6 g cm^{-2}
b) H^- → upper photosphere
   Paschen recombination → chromosphere
   Proton direct heating → impossible
   Electron direct heating → less possible than first two
c) This paper shows upper photospheric heating with $\mathcal{F}_{20}=10^{12}$ erg cm^{-2} s^{-1}, $\delta = 4$
d) Enchance Paschen lost due to nonthermal ionization
e) Their calculation **can't** explain strong contrast close to disk center because:
   those observation could be comtanminated by line emission
   and broadening Balmer lines (<6563)
f) Their calculation does not show λ dependence (linear relation)

20. Aboudarham & Henoux 1989

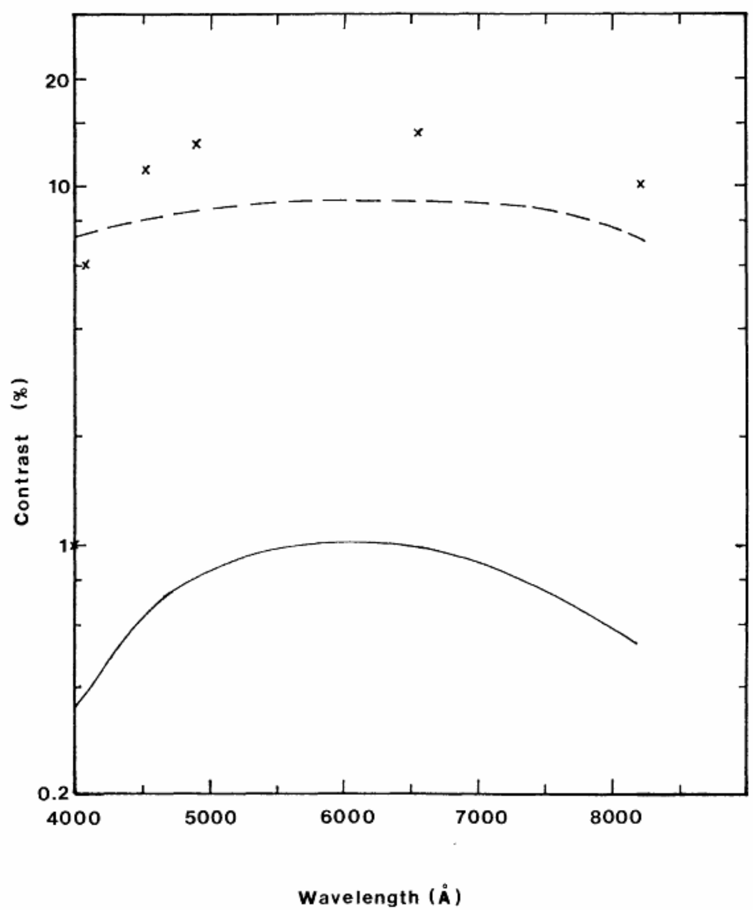


Fig. 7. Wavelength dependence of contrast C_ν between flare and quiet-Sun specific intensities, for heliocentric angle $\Theta = 53°$ ($\mu = \cos\Theta = 0.6$). Full line: non-thermal processes not included. Dashed line: non-thermal processes included. Crosses: observation by Neidig (1983) of 24 April, 1981 flare, modified data (see text).

1981-04-24 event has been re-measured by Neidig, but see next paper!

21. Neidig 1989 (a review)

a) Optical continuum is probably present in all flares but attains a detectable level of brightness in relatively few cases. {also see Zirin 1988}

b) WLFs are similar in many respects to stellar flares (Worden 1983) and represent the most extreme conditions, thereby presenting a major challenge to atmospheric models and energy transport mechanisms. {Importance of WLF studies}

c) Electrons > 900 keV penetrate to photosphere {weak B field case}

d) Livshits et al. 1981; MacNeice et al. 1984: chromosphere first and genertates a downward-propagating compression wave to heats deeper atmosphere with a delay to HXR about 10 seconds. {Backwarming also has a delay, but shorter}

e) 1980-07-01 is the only flare with LC differ from HXR and could be caused by protons

f) EUV luminosities could also produce WL, see Poland, Milkey and Thompson 1988

Summary of WLF energetics

	Flux in bright kernel (erg s^{-1} cm^{-2})	Luminosity (erg s^{-1})	Total energy (erg)
Typical WLF[a]	$1\text{–}2 \times 10^{10}$	$10^{27}\text{–}10^{28}$	10^{30}
Largest WLF[b] (1984 April 25)	6×10^{10}	2×10^{29}	$> 3 \times 10^{31}$

[a] Data from Neidig and Cliver (1983a).
[b] Sacramento Peak data, not published elsewhere.

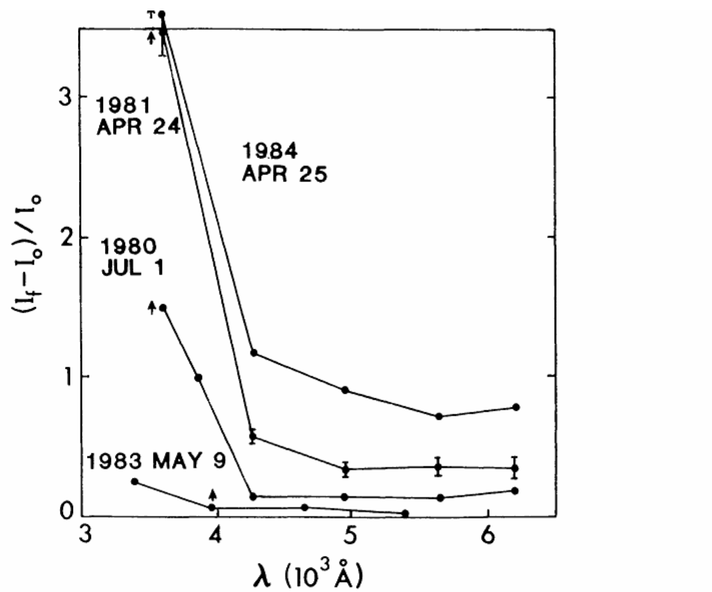


Fig. 1. Peak contrasts in the brightest kernels of four WLFs, measured in broad (20–50 Å) bands. Arrows identify data points that are lower limits. The 1981 April 24 flare has the most reliable spectral shape. Except for the 1984 April 25 event, data are from Canfield *et al.* (1986).

{1981-04-24 event is not consistent with last paper.}

22. Machado 1989 (XUV backwarming)

a) Replace H^- emission with radiative backwarming
b) Especially good for main-phase WL instead of impulsive phase

23. Mauas 1990 a&b

1982-06-15 WLF is caused by H^- emission

24. **Hudson et al. 1992 (a review of 4 events)**

The first G-band (4308 ± 15 Å) observation defined as WLF

XRT also has filter 4580 ± 70 Å

Table 2. NOAA summary information for the flares reported.

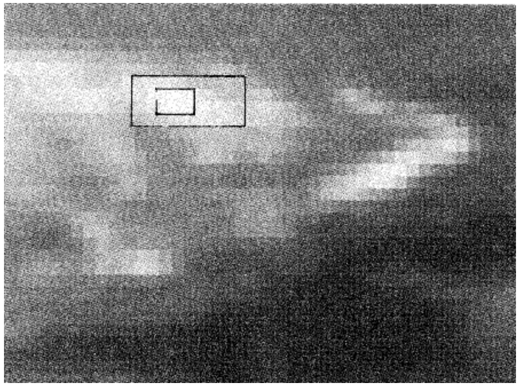
Date	Begin	Max	End	GOES	Hα	Location	Region	Radio 2.7	Fluxes 8.8	15.4
91 Oct 24	0231	0240	0256	X2.1	2N	S14E59	6891	84		10000
91 Oct 27	0537	0548	0712	X6.1	3B	S13E15	6891	3800	13000	13000
91 Nov 15	2233	2239	2254	X1.5	3B	S13W19	6919	1100	740	1900
91 Dec 03	1631	1639	1724	X2.2	2B	N17E72	6952	1200	1100	2300

Table 3. Yohkoh data.

Date	Peak time	SXT filter	SXT Peak brightness (I/I_0)	SXT total energy (erg)	Area (cm^2)	Duration (s)
91 Oct 24	0240	4308 Å	1.05	...	...	...
91 Oct 27	0548	4308 Å	1.07	...	...	...
91 Nov 15	2238	4308 Å	1.38	4×10^{30}	4×10^{18}	450
91 Dec 03	1639	4308 Å	1.08	8×10^{29}	7×10^{17}	350

25. Neidig et al. 1993

a) First time separates core and halo
b) Core follows HXR-35 better than halo
c) Chromospheric & backwarmed photospheric Emission



26. Neidig et al. 1993 (review of 86 WLFs)
{numbers increased by <26 in 10 yrs}

a) Spectral data excluded because the slit may not cover the brightest kernels.
b) 19 event observed with >4000 Å window
c) Models, see table II
d) Conclusion:
   Solely chromospheric origin does not work
   Middle photospheric sources may account for most WLFs
   Deep photospheric sources could not account for entire WL emission

TABLE II
Summary of WLF models[a]

Model	Atmospheric regime	Emission process	Optical thickness[b]	Description or remark
A	In or above chromosphere	H_{ff} or H_{fb}	Optically thin	Effectively isotropic (see text)
B	Chromosphere	H_{fb}	$\Delta\tau_V \leq 1.5$	Rectangular prism slab
C	Middle photosphere	H^-	$\Delta\tau_V \leq 4$	Rectangular prism slab
D	Deep photosphere	H^-	Black body	Vertical extent unspecified
E	Chromosphere	H_{fb}	$\Delta\tau_V \leq 1.5$	Array of unresolved prisms

[a] Vertical extent of these models is assumed to be 100 km, except for models A and D.
[b] Refers to optical thickness of the flare layer in the vertical direction, $\Delta\tau_V$.

27. Metcalf et al. 1990 (a review of heating mechanisms)

a) Ionization rate, hence the electron density is important to be observed

b) Two classes of heating mechanisms for emission from TMR

pre-existing energy in situ: H^- emission & dissipation of electric currents

transportation of energy from corona: all others

c) 8 mechanisms:

1. Heating by H^- absorption of Photospheric Radiation (Machado, Emslie & Mauas, 1986, hereafter MEM) heating correlates with ionization rate
2. Heating by dissipation of electric currents (Emslie & Machado, 1979) **{Current density $\propto$ B L^{-1}, therefore requires high spatial resolution observations}**
3. Direct heating by electrons
4. Direct heating by protons
5. Heating by SXR irradiation
6. Heating by UV irradiation
7. By Alfven waves
8. Chromospheric Backwarming

d) Observations (4571 & 5173 Å) of 5 flares M2.3, M1.0, M1.0, C2.0, C5.8 {?!}

e) Conclusion: Backwarming works for most samples, UV irradiation may also explain some events.

28. Gan & Mauas 1994
Chromospheric condensation could cause 7-8% continuum emssion for wavelengths larger than 4000Å

29. Beaujardiere et al. 1994
Chromospheric condensation is not the case for 1991-06-09 WLF (X10)

30. Black-light Flares
Driel_Gesztelyi et al. 1994
Ding et al. 2003 (2001-03-10 WLF observed in 8542Å)
BLFs are due to increase of H^- continuum absorption
BLFs are always observed on flares of dMe (red-dwarf star)
It requires high cadence observations

31. Fang et al. 1995
a) Up to now, less than 90 WLFs have been reported
b) Chromosphere temperature increased 1000-1500K, photosphere increased 300K
c) Believe that electrons can not directly deposit enough energy

32. Lin et al. 1996
Show Fe I 5324 flare was located in the low photosphere ~ 180 km above τ_{5000}=1. It was caused by chromospheric backwarming.

33. Matthews et al. 1998

a) Yohkoh's G-band camera works until 1992

b) {Two events, the LCs are different from our observations. The energy loss rate for these event are smaller than the case on 2003-10-29.}

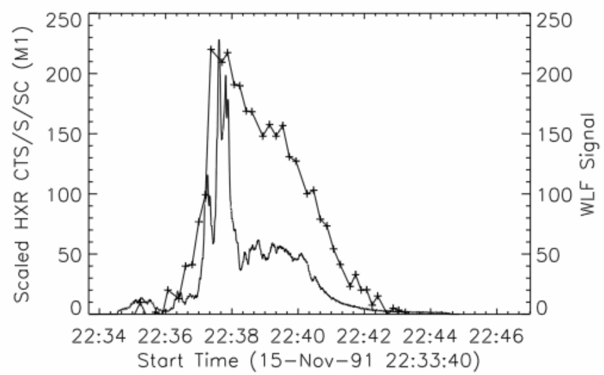


Fig. 2. The temporal variation of the white-light emission (+) and the hard X-ray emission observed in the M2 channel (solid thick line) for the WLF of 15 November 1991.

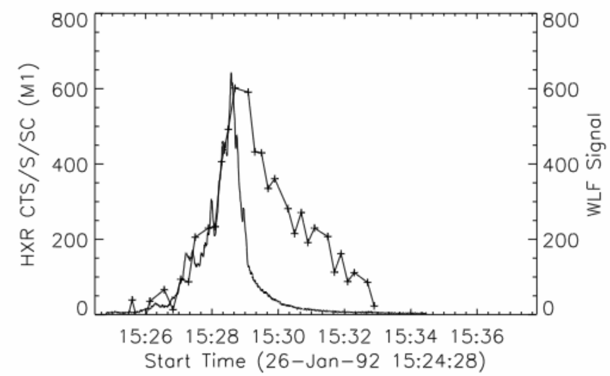


Fig. 3. The temporal variation of the white-light emission (+) and the hard X-ray emission observed in the M2 channel (solid thick line) for the WLF of 26 January 1992.

34. Ding 1999 & Ding et al. 1999 & Chen et al. 2001

a) Two types of WLFs:

Type I: The continuum emission from these models originates mainly from the recombination of hydrogen atoms in the chromosphere and thus shows a distinguishable Balmer or Paschen jump.

Type II: a heated upper photosphere. The continuum emission is then mainly due to the negative hydrogen emission in the upper photosphere. No Balmer or Paschen jump is present in this second case.

b) Super hot TMR and possible particle acceleration from lower atmosphere

35. Gan et al. 2000

The Balmer jump is produced directly by both roles of a condensation and non-thermal effects, while the continuum enhancement between 4000 and 7000 Å originates in the photosphere which may be radiatively heated due to the existence of a chromospheric condensation and non-thermal effects.

36. Sylwester & Sylwester 2000

TABLE I

The main characteristics of the investigated flares

No.	Date	UT	Hα	GOES	Location	NOAA	I_{max}/I_0	Correl.
1	24 Oct.1991	22:40	1N	M9.8	S12 E46	6891	1.06	GOES
2	15 Nov.1991	22:38	3B	X1.5	S13 W19	6919	1.35	L
3	03 Dec.1991	16:38	2B	X2.2	N17 E72	6952	1.05	M1
4	26 Jan.1992	15:31	3B	X1.0	S16 W66	7012	1.10	L
5	24 Apr.1992	19:19	2B	M1.2	N13 W00	7138	1.05	L

– Many small details of 1 arc sec size can be identified in the de-convolved SXT NaBan images.

– Observed WL flare-related emission is fine-structured and highly dynamic in character. Translation velocities may reach 100 km/s.

– There is no overall one-to-one correspondence between location of the WL emission and HXT emission and/or SXT emission.

– At the location of hardest (53–93 keV) X-ray emission, the WL emission is usually missing or weak.

37. Ding et al. 2003

Studied the 2001-03-10 flare. In the early phase, an electron beam is accelerated to bombard an unheated atmosphere; the non-thermal ionization by the beam results in an increased H^- opacity which then reduces the emergent intensity. With the flare development, the atmosphere is gradually heated (~20 s). In this period, radiative backwarming is the chief heating agent in the TMR and upper photosphere. {HXR increases about 20 seconds ahead WL}

38. Metcalf et al. 2003

In the 2001 August 25 flare, the TRACE WL and Yohkoh/HXT emissions are consistent with the classic type I WLF and originate in the chromosphere and temperature minimum region. The ultimate cause of the enhanced WL emission is the ionization and subsequent recombination of hydrogen. Energy deposited in the chromosphere by the electron beam is transported to the lower atmosphere by back-warming.

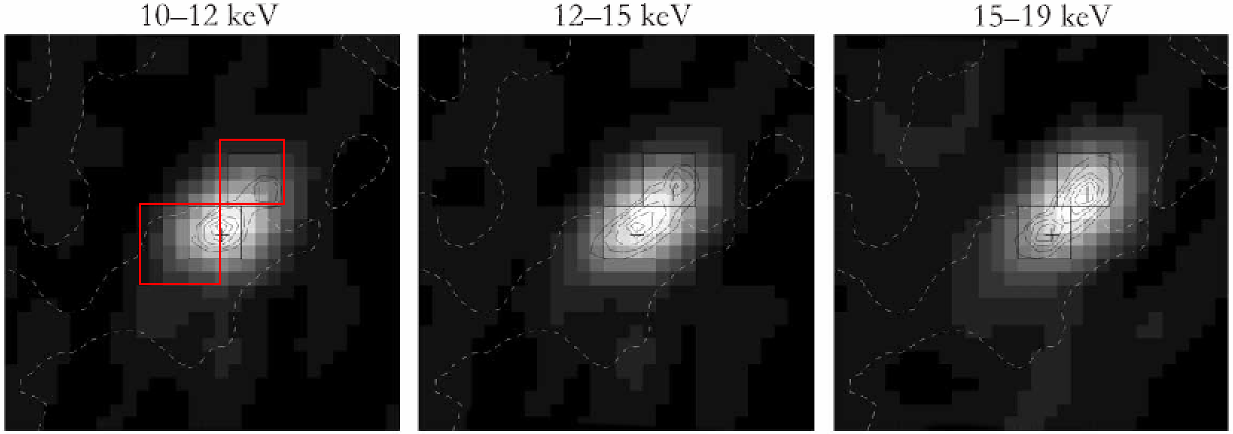
39. Chen & Ding 2005

FPs	HXR power	Hα + 6 Å enhancement (treated as continuum)
A	1 x 10^{10} ergs cm^{-2} s^{-1}	4 – 5%
B	0.8 x 10^{10} ergs cm^{-2} s^{-1}	8%

FP A, the atmosphere has been heated considerably and the coronal pressure is high in the early impulsive phase, which prevents nonthermal electrons effectively penetrating into the chromosphere;

FP B the preflare heating is relatively low, which allows an electron beam to easily penetrate into the chromosphere and produce the observed continuum enhancement via the radiativeback-warming effect.

{Comments: 1. Hα + 6 Å is true continuum?
2. FP B is a real FP?
3. Did not see spatial co-alignment between HXR & Hα
4. Where is the loop top? Especially in 10-12 keV.}



40. Matthews et al. 2003

A catalogue of white-light flares observed by Yohkoh

Table 1. List of WLFs indicating start times, flare location, GOES class, Hα classification, number of WLF kernels observed, WLF kernel location within the flare site, maximum WLF contrast relative to the pre-flare brightness in the flare location over the 4308 Å band, active region and sunspot class and corrected area as defined by Solar Geophysical Data, and whether or not a corresponding Type II or Type III radio burst was also observed in association with the event. [a] - magnetic classification of the active region is as given in Solar Geophysical Data: A= α, unipolar region; B = β, a bipolar group with a balance between the preceding and following spots; G = γ, a group in which polarities are completely mixed; BP = $\beta * p$, bipolar group where the preceding spots dominate; D = δ, spots of opposite polarity within 2.5° of one another and in the same penumbra; [b] - in millionths of a solar hemisphere; [c] - boundary between the penumbra and photosphere; [d] - boundary between the penumbra and umbra; [e] - for this event we have no pre-flare image of the active region in NaBan data and the flare ended in a data gap so that we were unable to determine a reliable value for the contrast in this case; [f] - the flare was at the limb making location determination unreliable; [g] - for this event we list two values of peak contrast based on two WLF kernels quite separate in time.

Flare #	Date	Start time	Location	GOES class	Hα class	# WLF kernels	WLF location	% Max. contrast	AR[a] class	Corrected[b] area	Type II association	Type III association
0	24 Oct. 1991	22:33	S12E46	M9.8	1N	1	photosphere	4.8	BGD	2290	N	Y
1	27 Oct. 1991	05:39	S13E15	X6.1	3B	4	PP[c]/PU[d]/PP//penumbra	–[e]	BGD	2470	Y	Y
2	31 Oct. 1991	09:09	S13W38	M1.0	1F	1	PP	2.3	BGD	1760	N	Y
3	2 Nov. 1991	06:44	S11W60	M9.1	1B	2	PU/photosphere	9.1	BGD	1350	N	Y
4	9 Nov. 1991	20:51	S14W69	M1.4	1B	1	photosphere	2.9	B	430	N	Y
5	10 Nov. 1991	20:05	S15E43	M7.9	1N	2	PU/photosphere	12.8	B	680	Y	Y
6	15 Nov. 1991	22:34	S13W19	X1.5	3B	2	photosphere/PP	26.3	BG	610	Y	Y
7	17 Nov. 1991	18:33	S12E78	M1.9	2B	1	photosphere[f]	1.1	A	10	N	N
8	3 Dec. 1991	16:34	N17E72	X2.2	2B	1	penumbra	30.0	B	210	N	N
9	11 Dec. 1991	15:04	S05E56	M4.0	1N	1	PP	7.6	B	340	N	Y
10	16 Dec. 1991	03:12	S10E69	C7.8	1B	1	PP	2.7	B	290	N	Y
11	16 Dec. 1991	06:37	S12E70	M1.6	2B	1	PP	6.3	B	290	N	Y
12	26 Dec. 1991	21:35	S15E23	M4.2	1B	3	photosphere/photosphere/PU	1.5	BGD	1050	N	Y
13	28 Dec. 1991	12:25	S17W38	M3.3	–	1	penumbra	5.2	BD	850	Y	Y
14	26 Jan. 1992	15:25	S16W66	X1.0	3B	5	photosphere - all	7.6	B	20	N	Y
15	30 Jan. 1992	13:56	S14W47	M1.8	1F	1	photosphere	5.2	B	100	N	Y
16	6 Feb. 1992	03:16	N05W82	M7.6	SN	2	-[f]	8.8	A	120	N	N
17	14 Feb. 1992	23:06	S13E02	M7.0	2B	5	penumbra - all	4.9	B	720	N	N
18	15 Feb. 1992	21:29	S16W13	M5.5	1B	2	penumbra/photosphere	6.4/3.2[g]	B	790	N	N
19	24 Apr. 1992	19:18	N13W00	M1.2	1B	1	photosphere	5.1	BD	180	N	Y
20	8 Jul. 1992	09:44	S11E46	X1.2	1B	2	PP/penumbra	10.6	BG	860	N	Y
21	16 Jul. 1992	16:55	S10W61	M6.8	2B	2	photosphere/photosphere	6.0	B	490	Y	Y
22	11 Aug. 1992	22:25	N12E80	M1.4	–	1	PP	5.5	BP	600	N	N
23	20 Aug. 1992	09:03	N16W27	M2.9	1B	1	PU	1.4	BGD	1290	N	N
24	6 Sep. 1992	09:02	S11W38	M3.3	1N	1	umbra	7.3	BGD	490	N	N
25	7 Sep. 1992	03:48	S10W49	M3.6	2B	1	PP/PU	6.0	BGD	780	N	N
26	10 Sep. 1992	22:51	N12E41	M3.2	2B	2	PU/PP	4.2	BG	240	Y	Y
27	5 Nov. 1992	06:19	S18W84	M2.0	–	1	photosphere[f]	5.7	B	120	N	N

41. Wang 2009

Study of white-light flares observed by Hinode

Table 1 Properties of Flares

Date	Peak Time	AR number	Location	GOES	Peak Contrast	Equivalent Area
2006 Dec 6	1013UT	10930	S07E68	X9.0	3.82	100.4 $arcsec^2$
2006 Dec 13	0240UT	10930	S06W23	X3.4	3.52	68.9
2006 Dec 14	2215UT	10930	S06W46	X1.5	1.51	46.5
2007 Jun 4	0513UT	10960	S05E51	M8.9	1.75	49.3
2007 Jun 3	0641UT	10960	S06E63	M4.5	1.79	16.8
2007 Jun 2	1035UT	10960	S09E73	M1.0	0.74	1.26
2007 Jun 9	1348UT	10960	S10W23	M1.0	0.0	0.0
2007 May 2	2348UT	10953	S14W17	C8.5	0.0	0.0
2007 Jul 10	0240UT	10963	S04E47	C8.2	0.51	0.61
2007 Jun 5	1613UT	10960	S07E30	C6.6	0.0	0.0
2006 Dec 7	0445UT	10930	S07E52	C6.1	0.0	0.0
2006 Dec 11	0818UT	10960	S04W02	C5.7	0.0	0.0
2007 Jul 10	1753UT	10963	S07E45	C5.2	0.0	0.0

Filter bandwidth:
Yohkoh 30 Å vs. Hinode 8Å

42. Allred et al. 2005 (Simulations)

a) The impulsive flare naturally divides into two phases, an initial gentle phase followed by a period of explosive increases in temperature and pressure. The gentle Phase is shorter in strong flares (~X class) than in moderate flares (~M class).

{gentle phase is a preheating, like some Hα observations?}

b) The optical continuum also brightens, showing a peak enhancement of 5% for F10 (comparable to observed enhancements) and 30% for F11.

F10 → $\mathcal{F}_{20} = 10^{10}$ ergs cm^{-2} s^{-1}

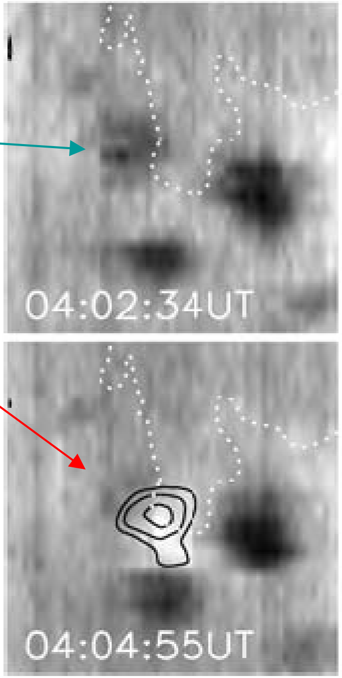
{Strong flux indeed affects the WL a lot}

c) We find that XEUV back-warming contributes less than 10% of the heating, even in strong flares.

43. Li et al. 2005

a) On 10 March 2001, the flare made a small sunspot almost disappear in the continuum image for about 3 min

b) **According to Machado *et al.* (1986),** there exist two extreme types of WLFs: type I that shows a Balmer jump and a hydrogen free-bound (Hfb) continuum; type II that has no Balmer jump but predominantly a negative-hydrogen (H^-) emission. **Type I WLFs, the enhanced continuum is closely associated with non-thermal Electrons released from the upper atmosphere. Type II WLFs may originate from a heating source located in the lower atmosphere**



44. Hudson et al. 2006 **WHITE-LIGHT FLARES: A TRACE/RHESSI OVERVIEW**

a) “White light.” refers to continuum emission in **excess of the photospheric background**

b) The white-light continuum is usually a phenomenon of the impulsive phase (ˇSvestka, 1970; Hudson, 1972), although the literature (and this paper, see below) contains examples of other kinds (e.g., Neidig *et al.*, 1993; Matthews *et al.*, 2003)

c) Rare events: 1983 (Neidig and Cliver) listed 60
1993 (Neidig, Wiborg and Gilliam) listed 86

d) From 2002 to 2004, 33 event observed by TRACE, with RHESSI, the number reduced to 11. {The events in 2003-Oct & Nov are not included.}

e) TRACE WL = 1700 Å – UV response

44. Hudson et al. 2006 **WHITE-LIGHT FLARES: A TRACE/RHESSI OVERVIEW**

Conclusion:

(1) For a given GOES class, the TRACE white-light flare emission in the TRACE appears brighter (higher contrast) than that seen in narrower bands, e.g., from ground-based observations. {shorter wavelength and line contamination ?}

(2) TRACE UV images (1700 Å continuum) resemble the white-light images, but have far greater contrast. In some cases the white light may be distinguishable from the UV and have a stronger association with hard X-ray time profiles.

(3) White-light emission is highly localized (intermittent) both in space and time, even with the superior TRACE resolution and sampling.

(4) White-light emission correlates well in detail with hard X-ray emission.

(5) In some cases, white-light emission can clearly be seen from loop tops, as well as ribbon/footpoint structures. **({doubts Chen & Ding 2005}**

Future observations with another order of magnitude of resolution both in space and in time would therefore be highly interesting.

45. Donea et al. 2006 (**SEISMIC EMISSION related to WLFs)**

a) The detection of the first sunquake by Kosovichev and Zharkova (1998) Nature, 2006 December 13 using Solar Optical Telescope (SOT)

b) Summary:

1. Moderately energetic flares can be more acoustically active than some of high energy.
2. There is a strong association of compact seismic signatures from the M9.5 flare with sudden excess WL emission.
3. The conspicuous spatial and morphological correspondence between the WL and the seismic emission signatures suggest that the seismicity of the active region is related to sudden heating of the low **photosphere**.
4. The fraction of energy emitted into the subphotosphere as seismicwaves remains a small fraction of the total energy released in the flare. However, according to rough estimates based on simple models this appears to be consistent with seismic emission driven by photospheric heating.
5. The persistence of a sudden, co-spatial WL signature in flares where no energetic protons are evident is consistent with acoustic emission driven by back-warming of the low photosphere by radiation from a heated overlying chromosphere. While we do not regard this issue as closed at this point, the sharp coincidence between acoustic emission and the sudden appearance of continuum emission nevertheless can be regarded as strong support for the back-warming theory where it applies to the lowphotosphere, failing other realistic avenues for heating of the low photosphere.

Another sample could be found in **Martínez-Oliveros et al. 2008**

46. Fletcher et al. 2007

TRACE + RHESSI

TABLE 1
LIST OF *TRACE/RHESSI* WHITE-LIGHT FLARES ANALYZED

Date	Flare Start	Class	Location	*GOES* Peak	WL Peak	HXR Peak	HXR Image Time	γ	$P \geq 25$ keV (10^{27} ergs s^{-1})	$P \geq 50$ keV (10^{27} ergs s^{-1})
2002 Jul 26	18:57	M1.0	S21 E21	19:03	19:01:56	19:02:00	18:59:28 - 19:02:0	7.4 ± 0.1	0.48 ± 0.05	0.06 ± 0.007
2002 Oct 4	05:34	M4.0	S19 W09	05:38	05:36:46	05:35:50	05:35:40 - 05:36:0	4.42 ± 0.08	16.0 ± 1.4	15.0 ± 1.3
2002 Oct 5	10:39	M1.2	S20 W24	10:46	10:41:58	10:42:00	10:41:20 - 10:42:24	4.667 ± 0.002	0.9 ± 0.001	0.714 ± 0.001
2002 Nov 12	17:58	C9.9	S11 W75	18:18	18:16:04	18:16:10	18:15:48 - 18:16:2	4.75 ± 0.06	2.3 ± 0.2	1.7 ± 0.2
2003 Jun 12	01:04	M7.3	N13 W65	01:30	01:23:45	01:26:20	01:23:00 - 01:24:3	7.30 ± 0.64	5.1 ± 1.1	0.6 ± 0.1
2003 Oct 23	02:35	M2.4	N03 E15	02:41	02:39:49	02:39:50	02:39:34 - 02:40:1	5.93 ± 0.04	21.2 ± 1.8	6.9 ± 0.6
2004 Jan 9	01:33	M3.2	N02 E49	01:44	01:40:17	01:40:30	01:39:44 - 01:40:4	6.0 ± 0.1	6.1 ± 1.0	2.7 ± 0.6
2004 Jul 22	00:14	M9.1	N03 E17	00:32	00:30:31	00:30:10	00:29:40 - 00:30:41	5.6 ± 0.1	16.2 ± 1.3	6.6 ± 0.5
2004 Jul 24	13:31	C4.8	N04 W16	13:37	13:34:46	13:34:40	13:34:45 - 13:35:17	4.30 ± 0.03	5.9 ± 0.4	5.8 ± 0.4

We find that the power required by the white-light luminosity enhancement is comparable to the electron beam power required to produce the HXR emission only if the low-energy cutoff to the spectrum is less than 25 keV

Thus the correlation with 50 keV X-ray emission noted by Neidig (1989) and others must not properly represent the energetics.

Comments: 1. X class vs. M class
2. Pure continua vs. ???

47. Wang et al. 2007

Using TRACE WL and 1700 Å data, we have analyzed the M9.1 two-ribbon flare that occurred on 2004 July 22. Our main results are summarized as follows:

1. We found many strongly enhanced small patches in TRACE WL images during the impulsive phase of the flare.
2. The enhancements in the WL and 1700 Å bands are highly correlated, and they are also closely correlated with the HXR emission.
3. The UV brightenings have a typical size of about 1″–2″ and a lifetime of about 30–60 s. The intensity enhancement is about 150–200 times the mean value of the quiet-Sun. We propose that these brightenings are related to non-thermal processes.

48. Jess et al. 2008

Highest spatial setup: up to 0.034 in Ca II filtergram

Up to 300% contrast during flare

Speckled results

Smallest flare kernel ~ 1.0 x 10^{15} cm^2

49. Babin & Koval 2008

Compared two WLFs: X12 and M2.6

50. Xu et al. 2004 & 2006

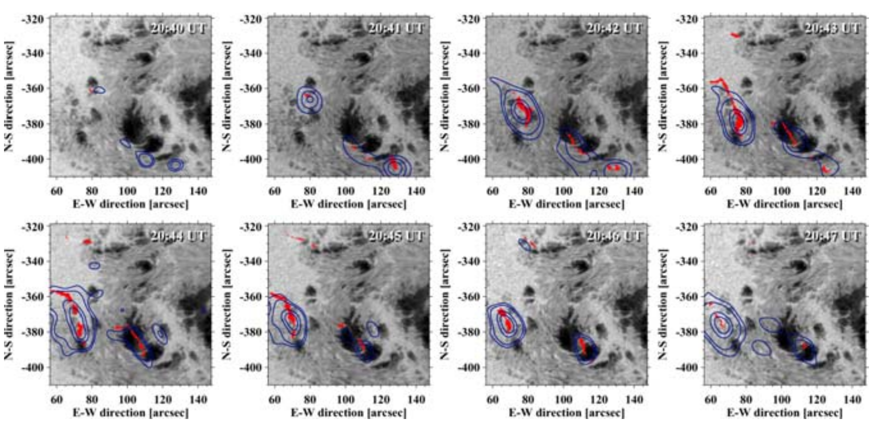
1st near Infrared ('real') continuum observation of WLFs

1st high resolution observation of WLFs with high order AO correction

1st AO + Speckle observations

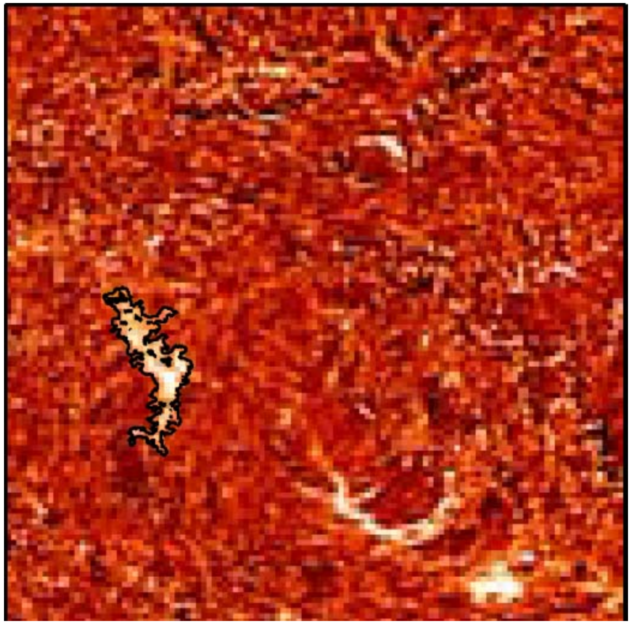
Highest temporal resolution ever

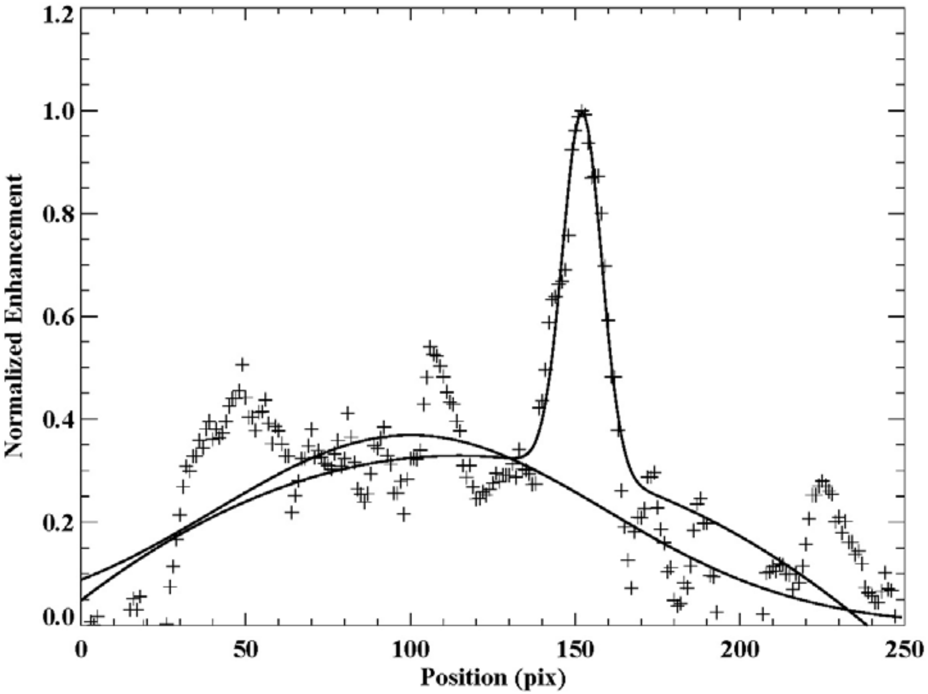
1st time show core-halo structure clearly



Event	October 29	November 2
Disk Location	S17W10	S17W63
GOES X-ray Class	X10	X8
Start Time	20:39 UT	17:15 UT
Peak Time	20:42 UT	17:17 UT
NIR Peak	25%	66%
V_5200 Peak	37%	76%
G-band Peak	75%	230%
V (km/s)	29	24
E (V/cm)	23	22

51. Xu et al. ???





C_halo ~ 1/3 C_core = 8%

Most recent numerical simulation ~13% (Cheng et al. 2009), electron flux ~ 10^{11} erg cm^{-2} s^{-1}

52. Cheng et al. 2009*

Radiative Simulation

a) Direct heating >> Radiative heating in Chromosphere, impulsive
   Radiative heating >> Direct heating in photosphere, gradual

b) Max enhancement in 15400 is 13% vs. 66% in 15600 observed by Xu et al. 2006

c) Max $\mathcal{F}_{40}$ → 10^{11} ergs cm^{-2} s^{-1} and $\delta = 3$

d) Delay of 1.7 s between low and high atmosphere layers

53. Isobe et al. 2007

a) Assuming that the interpretation of Xu et al. (2006) can be applied to our event, i.e., direct heating by particle beams in the core (leading edge) and radiative back-warming in the halo (diffuse part), we made a simple model to measure the upper limit of the depth of the layer at which the diffuse emission occurs.

b) The best-fit parameters are h = 124km for the G band, and h = 300km for 6302.

c) The original energy release set could be estimated by 25 keV penetration depth.

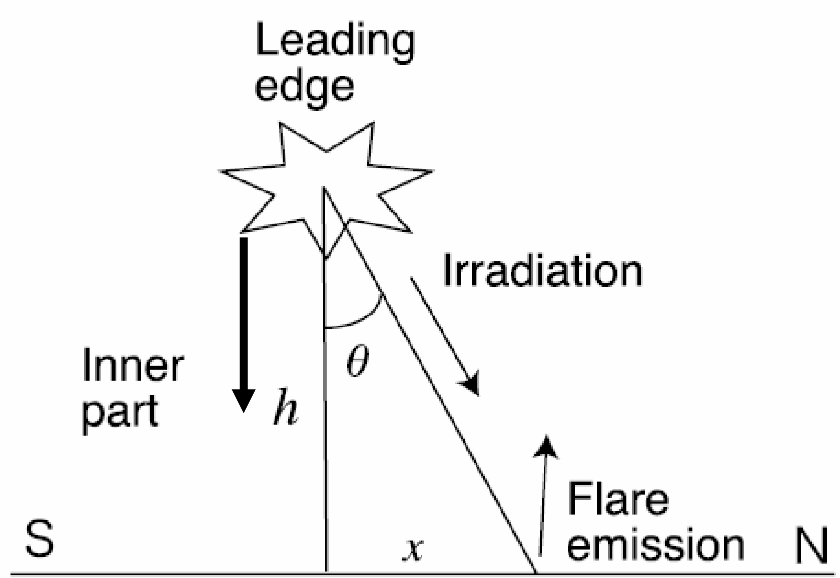


Fig. 6. Schematic illustration of the model.

54. Watanabe et al. 2009*

a) Compare HXR with WL of 2006-12-14 X1.5 flare observed by Hinode and RHESSI

b) HXR sources (50 – 100 keV) in chromosphere (600 - 6500 km above photosphere)
WL (G-band) sources in upper photosphere (0 – 100 km above photosphere)

c)The total power of electrons above ~ 40 keV roughly matches WL power. {*Which means no in situ energy need for this flare.* }

Comments: 1. Source identification in HXR is not accurate therefore the imaging-spectra are not reliable.

2. Fitting processes are not consistent at different time periods, therefore the statistical conclusion is not so meaningful.

Proton events:

1. Svestka 1971 estimated Neutrons flux generated by WLF
Protons impinging into the photosphere products neutrons

2. Krivsky & Yen 1976

3. Ramaty et al. 1975

4. Hudson et al. 1980

5. Hurford et al. 2006
RHESSI imaging of three flares (2003 October 28 and 29 and November 2) in the 2.223 MeV gamma-ray line with **angular resolution as high as 35”.**
The gamma-ray–producing ions appear to be **accelerated by the flare process** and not by a widespread shock driven by a fast coronal mass ejection.
The **28 October event yielded the first such image to show double-footpoint** gamma-ray line sources.
These footpoint sources straddled the flaring loop arcade but were displaced from the corresponding electron-bremsstrahlung emission footpoints by 14 and 17”5. This implies spatial differences in **acceleration and/or propagation between the flare-accelerated ions and electrons.**
Therefore, if WL correlates with HXR then nothing to do with Gamma-ray

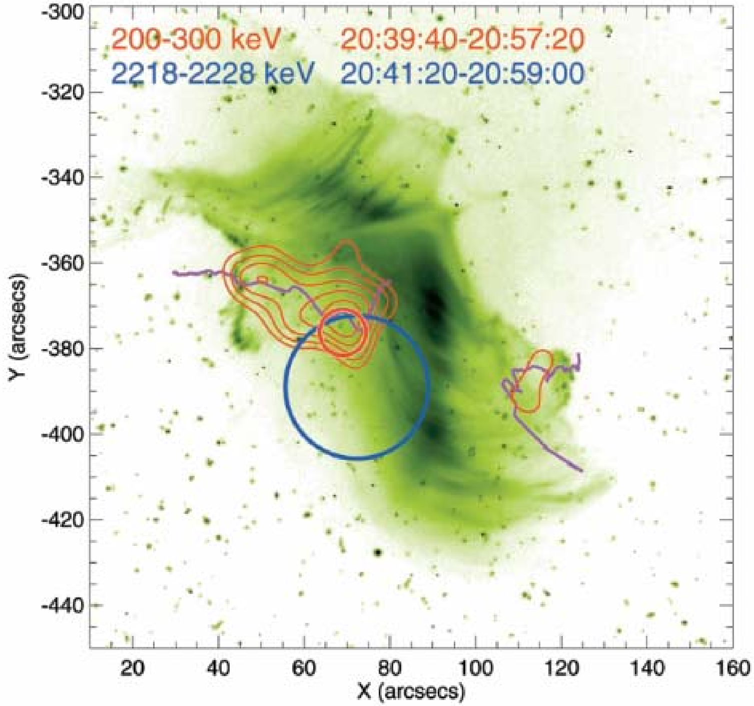


FIG. 3.—The fine red (50%–90%) contours show the 200–300 keV high-resolution map for the 2002 October 29 event superposed on a *TRACE* 195 Å image. The thick red and blue circles are the centroid locations with 1 σ error radii for RMC 9 imaging at 200–300 and 2218–2228 keV, respectively. The purple lines illustrate the motions of the 200–300 keV footpoints.

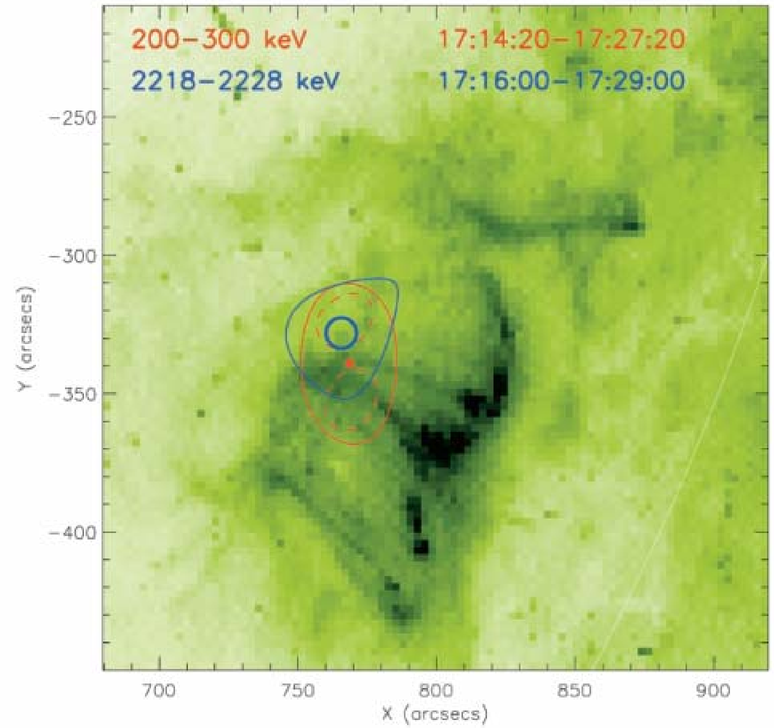


FIG. 4.—Overlay of 200–300 keV (*red contours*) and 2218–2228 keV (*blue contour*) sources onto a postflare *SOHO*/EIT image for the 2002 November 2 event. The dashed and thin solid red 50% contours show the result of 200–300 keV mapping with 7″ and 35″ resolution (RMCs 3–9 and 6+9), respectively. The 35″ map cannot quite resolve the double-footpoint source revealed by the high-resolution map and so has an elongated profile. The thin blue 50% contour is the corresponding RMC 6+9 map at 2218–2228 keV. The thicker 1 σ error circles show the RMC 6 source centroid locations.

	A	B	C	D	E	F	G	H	I
1	Flare	Area (cm^2)	Class	Center or Limb	Umbra	Wavelength (Å)	Max Emission	Ref	Observatory
2	1859						>200%	Carrington	
3	1938					3220		Dobbie et al. 1938	
4	1960-09-03UT01:05	1.3 x 10^18		Limb	No			Angle 1961 (PASP)	
5	1967-05-23UT18:40	2 x 10^17				5740	>16%	Hudson 1972	NSO/SP
6		5.8 x 10^17					>12%		
7	1973-09-07UT			Limb?				Krivsky & Yen 1976	
8	1973-09-01UT23:04			center	Yes			Svestka 1976	
9	1972-08-07UT15;19					4950	0.25	Machado 1976	
10						5900	0.11		
11	1974-09-10UT21:48					Halpha + 1		Hiei 1982	BBSO
12						3646~4000	7.50%		Norikura Solar Observatory
13						3600~3646	14%		
14	1980-07-01UT16:27					X, γ rays		Ryan et al. 1983	GRS/SMM
15						Multi < 6203	up to 250%	Zirin & Neidig 1981	BBSO
16	1974-07-04UT13:53					visible continuum		Feibelman 1974 ...	
17						Radio		Tlamicha 1974	Ondrejov radiospectrograph
18	1981-04-24UT13:56			center	Yes	Spectral 3610~4275		Neidig 1983	NSO/SP
19						filtergram 3610 ~ 6203	360% ~ 40%		
20	1970-03-26UT20:20		X1	limb		Spectral 3558 ~ 5920		Boyer et al. 1985	NSO/SP
21	1982-06-15UT15:15		X1	limb	no	Spectral 3550 ~ 9100		Mauas 1990	NSO/SP
22	1989-08-16UT01:07		X20	extreme limb		Halpha, 5600		You et al. 2003	Hiraiso, Kawaguchi (Museum)
23	1991-11-15UT22:34	3 x 10^16	X1.5			4308	38%	Hudson 1992	SXT/Yohkoh
24	1991-06-04UT03:39	3 x 10^16	X12	east limb	Yes	Green?		Sakurai et al. 1992	SFT/NAOJ
25	1991-06-09UT01:40	4 x 10^17	X10	center		G-band			
26	1991-06-011UT02:06	2 x 10^16	X12	center	Yes	G-band			
27	1991-03-27UT04:44	4.4 x 10^17			close to	4100	80%	Korobova 1992	Tashkent
28	1991-06-15UT08:10		X12	limb	penumbra	Spectral 6517-6598		Babin & Koval 1992	
29	1989-03-07UT14:55		X1.8	limb	Yes	Halpha +/- 3 & 5000	220%, 20%	Neidig et al. 1993	NSO/SP
30	1984-04-24UT23:54	<2.0 x 10^19	X13	center		3610 - 6203	330% - 80%	Neidig et al. 1994	NSO/SP
31	1991-10-24UT02:38		X2.1	center		Spectral Hα, Hβ, Hγ, NaID, CaIIK		Fang et al. 1995	STT/NJU
32	1991-10-27UT05:39		X6.1	center		Spectral Hα, Hβ, Hγ		Lee et al. 1996	STT/NJU
33	1991-06-04UT					Hβ & Fe I 5324 (photosphere)		Lin et al. 1996	BAO
34	1993-06-24UT07:35		M9.7			Hβ & Fe I 5324 (photosphere)		Lin et al. 1996	BAO
35	1974-10-11UT03:29			center				Ding 1999	
36	2001-03-10UT04:00		M6.7	center		Hα, 8542 continuum, radio	5%	Liu et al. 2001	NJU & BAO
37	2001-08-25UT16:29		X5.3					Metcalf et al. 2003	TRACE & Yohkoh
38	2002-09-29UT06:39		M2.6	center		Hα imaging spectral, HXR	8%	Chen & Ding 2005	STT/NJU & RHESSI
39	2002-07-15UT20:03		X3	center		WL, Hα, radio		Li et al. 2005	several...
40	2002-09-30UT01:50		M2.1	center		Hα imaging spectral, HXR	10%	Chen & Ding 2006	STT/NJU & RHESSI
41	2004-07-22UT00:32		M9.1	center		1700 Å		Wang et al. 2007	TRACE
42	2007-08-24UT11:15	1 x 10^15	C2.0	center		Hα and Ca II		Jess et al. 2008	Swedish Solar Telescope
43	2002-07-23UT00:29	X4.8		Limb		Radio & HXR			RHESSI & Wind & SRBL
44	**2006 Dec events**		X			G-band, HXR			Hinode & RHESSI
45	**Halloween events, 2003**		X	both	Yes	wide range			

Summary:

1. WLFs are flares.

2. Electron and protons carry the energy from reconnection set to WL emission set. But protons are questionable. See Hurford 2006, spatially not correlated.

3. Most previous studies concentrated in short wavelengths.

4. High spatial/temporal resolution observations reduce the energy requirement.

5. No model or calculation considered B which affects column density a lot, especially in umbra areas.

6. What does 'originate' mean? The energy source? Where does the WL emission come from?

Open Questions:

1. Where does WL emission come from, photosphere or chromosphere?
2. If WL from photosphere, is the energy transported from corona or in situ and how?
3. How does the opacity change affect WL origin?